Ultrahigh-Vacuum Diffusion Bonding

Controlled interfaces for research and manufacturing

We have designed and constructed an ultrahigh-vacuum (UHV) diffusion-bonding machine with a unique capability for producing highly controlled homophase and heterophase interfaces. We can heat flat-polished single or polycrystals of materials with controlled surface topography up to 1500°C in ultrahigh vacuum. Surfaces of annealed samples can be sputter cleaned and characterized prior to bonding. Samples can then be precisely aligned crystallographically to obtain desired grain boundary misorientations. Material couples can then be bonded at temperatures up to 1500°C and pressures over 20 MPa. This system enables us to investigate and isolate process parameters for production and performance of materials bonds.

Bonding machine

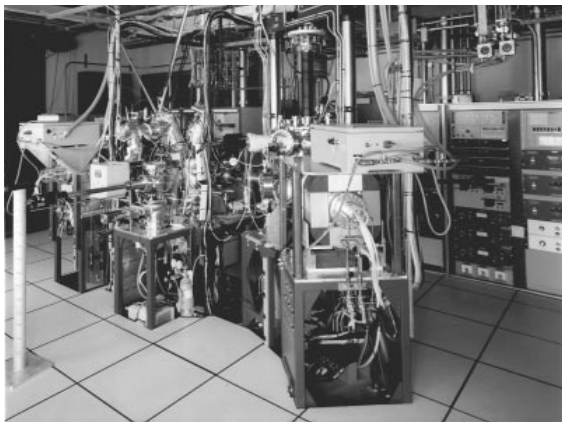
The UHV diffusion bonding machine has four chambers: a surface analysis, diffusion bonding, annealing, and surface modification chamber. Typically, a sample is first introduced into the annealing chamber via an airlock chamber and annealed in ultrahigh vacuum to 1500°C to stabilize the microstructure.

APPLICATIONS

- *Metal grain boundaries*
- *Metal/ceramic interfaces*
- *Atomic structure*
- *Mechanical properties (including fracture)*

After annealing, a rail system transports the sample to the surface analysis, surface modification, or bonding chamber. In the surface analysis chamber, rotating sample surfaces are sputter-cleaned with a 500-eV ion beam at an incidence of 15°. The sample can be heated at the same time to about 1000°C to purify its near-surface region. Surface cleanliness and levels of surface doping are assessed with Auger electron spectroscopy, low-energy electron diffraction, and static secondary-ion mass spectrometry.

In the bonding chamber, samples are stacked on the lower ram of the diffusion bonding press. Single crystals can be oriented to produce a bicrystal. The entire stack is then raised into the furnace for bonding. An airlock is also incorporated in the diffusion bonding chamber to facilitate removal of bonded samples.



The UHV diffusion bonding machine represents a unique capability to optimize process parameters for materials bonding.

Fracture testing

We have fabricated samples for fracture testing in this facility. Samples were diffusion bonds of polycrystalline, high-purity aluminum and aluminum–magnesium alloy foils (approximately 100-µm thick), to high-purity polycrystalline alumina rods (2.0-cm long). Foil geometry was selected to minimize contribution of bulk plasticity to fracture-resistance measurements. Magnesium content was varied to change the material yield strength. Research results could improve design of metal/matrix composites (MMCs). We conclude that as strength of the matrix increases, the tendency toward interfacial fracture in a composite material also increases. Optimum MMC properties may be obtained by careful consideration of loads, yield strength of the matrix, and reinforcement separation distance.

Availability: We are interested in collaborating with industry on problems associated with probing the effect of impurities, flaws, and inclusions on adhesion and bonding at internal interfaces.

Contact

Wayne E. King
Phone: (510) 423-6547
Fax: (510) 423-7040
E-mail: weking@llnl.gov
Mail code: L-356

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